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Economic Value of Preemergence Herbicides in Soybeans

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ECONOMIC VALUE OF PREEMERGENCE HERBICIDES IN SOYBEANS

by

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Submitted in Partial Fulfillment of the Requirements for the
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With the widespread epidemic of herbicide resistance in weeds, and relatively low cash market prices, the economic sustainability of weed management programs in soybeans is of critical importance. Growers in Southern Illinois and across the Midwest face a wide variety of competitive weeds, with some populations expressing resistance to multiple herbicides, which can make it difficult and costly to select an effective herbicide program. Over-reliance on broad-spectrum herbicides such as glyphosate has helped to create this shift in herbicide resistant weeds. Utilizing data collected in southern Illinois during the 2016 and 2017 growing seasons by Matt Geiger, we will test the economic sustainability of various herbicide programs common in Southern Illinois. A regression model was used to assign yield benefits or reductions to six different soybean systems and their respective herbicide programs. Economic return on investment was greatest when using preemergence (PRE) followed by postemergence (POST) herbicide programs across all soybean systems. Treatment costs were comparable for all soybean systems, implying that weed control and yield was most important.

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CHAPTER 1

INTRODUCTION

The US is the leading soybean producer and exporter in the world, and the US soybean crop is the largest source of animal protein in the world, as well as the second largest source of vegetable oil. In 2018 acres planted to soybeans in the U.S. exceeded corn acres for the first time since 1983 with 88.1 million acres of soybeans being harvested. This produced approximately 4.5 billion bushels of soybeans. The average price for soybeans in 2018 was $9.15 per bushel with an estimated total value of $39,133,978,000 (USDA 2019).

Since the development of glyphosate resistant (GR) soybeans in 1996 there has been a tremendous increase in the amount of acres of crops that utilize this broad spectrum herbicide. With this large increase in glyphosate dependent weed management programs, weeds have begun to develop resistance to herbicides as well. Weed resistance in row crops is costing producers heavily; their competition with crops costs an estimated $100 billion dollars globally each year according to Redbond (2015).

There is a large collection of literature that tests the efficacy of specific herbicides and their control of weeds, and soybean injury rates, and economic return on investment (EROI). Geiger (2018) contributed to this data by comparing a variety of PRE-only, POST-only, and PRE-fb-POST herbicide programs side-by-side within the following multiple different soybean systems: The soybean systems included were: conventional, glyphosate-resistant (1st and 2nd generation), glufosinate-resistant, dicamba + glyphosate-resistant.

Row crop herbicide studies are typically subjected to various ANOVA testing for statistical significance. This study takes a different approach and uses multiple regression analysis to assess yield and economic return on investment (EROI) within similar crop and weed management studies.

CHAPTER 2

REVIEW OF LITERATURE

In order to assess current weed management practices and potential future issues in our cropping systems we must look back on herbicide usage and adoption from the past. It is also important to understand how growers perceive the overall advantages of using the GR-based system and how their management practices affect weed control and species composition

In the early 2000's it was evident that transgenic crops were growing at a rapid pace in the US compared to other states across the world. Bonny (2008) expressed some of the factors that lead to such a wide-spread Genetically Modified (GM) crop adoption in soybeans leading up to 2007 were agronomics, and environmental impacts (2008). In 2007 91% of all land dedicated to soybean production utilized GM crops. Some factors contributing to this progression in the US is very briefly, the rapid development of biotechnology in the US was favored by the contextual framework of the country; undeniably, there exists in the US a firm faith in progress, business and innovation. The various benefits of producing transgenic soybeans (easier weed control, extended window of application, reduced herbicide prices) outweighs the negatives of (increased seed costs, and any negative economic factors).

Kruger, et al., (2009) found that growers using a GR Corn/Non-GR crop rotation were the most likely to report increase in weed pressure of up to 7%. Up to 11% of growers were not aware of any problematic weeds on their farms. This points towards to the possibility that growers are paying less attention to weeds on their farms as a result of the efficacy of glyphosate.

During 2005, non-glyphosate herbicide programs were being replaced with glyphosate as the main herbicide. Researchers were already looking at the negative effects of weed management programs relying only on glyphosate and indicated that there may be a shift towards the use of soil applied herbicides, due to concerns about glyphosate resistance and a number of other factors (Young, et al., 2009).

With a wide variety of herbicide technology and genetic trait packages for soybeans available today it can be difficult to select a proper weed management program. However, the agriculture industry has what it refers to as best management practices (BMPs) for nearly every aspect of a farming operation, especially weed management. These BMPs are developed in coordination with university research as well company recommendations. Standard practices also exist and are used to describe common practices observed in the industry by growers (Edwards, et. al., 2014).

Utilizing a wide diversity of crops, geography, and crop systems; Edwards, et. al., (2014) set out to compare the economics of herbicide resistance Best Management Practices (BMPs) and Standard Weed Management Practices (SPs) over a five-year period. Results showed that BMPs typically cost about 30% more than SPs. However, the net returns did not differ between the BMPs and SPs either. Although BMPs typically cost more, the improved weed control contributes to net profits similar to SPs. Growers must consider the sustainability of their weed management programs. This study proves that BMPs are sustainable both economically and agronomically.

One common BMP is for growers to utilize both pre-emergence (PRE) followed by (fb) post-emergence (POST) herbicides. These herbicides should have multiple effective modes of action (MOA) in order to kill a broad spectrum of weeds and fight the potential evolution of weeds resistant to herbicides. With the introduction of broad-spectrum herbicides such as glyphosate (Roundup Ready), it is common for growers to use SP’s of applying the same broad spectrum POST herbicide multiple times in the same growing season without the utilization of soil-applied herbicides due to the effectiveness of glyphosate as a POST treatment. This can select for herbicide tolerance in plants that fail to be terminated and can rapidly increase the development of herbicide resistant weeds. Growers are currently re-adopting the concept of using soil-applied herbicides due to the increasing levels of herbicide-resistant weed biotypes (Norsworthy et al., 2012).

There are many sources in the literature that test the efficacy and weed control of individual or multiple herbicides in different application methods and environments, with different problematic weed species. Craigmyle, Ellis, and Bradley (2013) compared and contrasted the summer annual grass and broadleaf weed control provided by PRE fb POST, two-pass POST, one-pass POST residual, and one-pass late POST programs that contain glufosinate plus 2,4-D. PRE fb POST herbicide programs had the highest overall weed control (94%) and provided better waterhemp control than two-pass POST herbicide programs. No notable yield differences were observed between the herbicide programs as they all provided greater than 80% weed control. Herbicide programs that contain both 2,4-D and glufosinate treatments can help to control waterhemp and other problematic weed species.

As more weeds begin to develop Glyphosate Resistance (GR), protoporphorinogen oxidase- (PPO-) inhibiting herbicides have been shown to still effectively control these GR weeds. Aulakh (2016) studied different PPO-inhibiting herbicides applied post at 10-cm and 20-cm tall weeds to assess weed control and soybean injury at different trifoliate stages. The three GR weeds assessed were common waterhemp, giant ragweed, and kochia. The different PPO-Inhibiting herbicides showed very little difference in % control of GR weeds at 10-cm and 20-cm tall applications. However, fomesafen and fomesafen + glyphosate caused the least amount of injury to the soybeans.

Palmer amaranth, a relative of waterhemp is another problematic weed, which is spreading across the Midwest. Chahal, Ganie, and Jhala (2018) set out to determine the efficacy of soil-residual PRE herbicides fb residual herbicides in tank mixture with foliar POST herbicides for photosystem II- (PS II-) and hydroxyphenylpyruvyldioxegenase- (HPPD-) inhibitor-resistant Palmer amaranth control. They also assessed crop yield and net economic return from these applications in GR maize. This experiment was conducted on a grower's field with confirmed PS-II and HPPD-inhibitor-resistant Palmer amaranth.

Fifteen different herbicide programs were utilized for the study. The results indicated that PRE fb POST programs provided the higher yield and economic return than POST only programs. Concluding that effective control of multiple herbicide-resistant Palmer amaranth can be achieved with PRE fb POST programs that include herbicides with overlapping residual activity to maintain season-long control (Chahal 2018).

Common ragweed is another problematic weed in southern Illinois. Barnes, et. al., (2017) tested the efficacy of preplant (PP) herbicides followed by (FB) glufosinate alone or in a tank mixture with other herbicides. Thirteen different herbicides were utilized at four different application timings. Gross profit margin was calculated as gross revenue minus herbicide and application costs. PP followed by EPOST treatments resulted in the highest yields of any application timing combination.

The studies listed above all point towards the need for a two-pass BMP in soybeans. However, today there are new soybean systems with resistance to different herbicides, allowing growers more options for weed management than ever before. The data for this research contains all of the soybean systems available to growers prior to the release of 2,4-D + glyphosate-resistant soybeans and assesses possible and similar herbicide programs to derive an economic return on investment (EROI) for each soybean system and herbicide program. Geiger (2018) looked extensively at weed control of the programs and found little difference between the soybean systems. His results were subjected to ANOVA testing. This research will utilize regression analysis to test for statistical significance in yield differences between the soybean systems and herbicide programs.

CHAPTER 3

DATA AND METHODS

Data for this study was conducted and collected by Geiger (2018), during the 2016 and 2017 growing seasons across two locations in southern Illinois: Belleville (38°31'15.53"N 89°50'41.27"W) and Dowell (37°55'58.23"N 89°14'45.58"W), with natural weed infestations. Belleville was subjected to a common tillage regime, while no-tillage practices where used in Dowell. A pre-plant burndown application was made to establish weed-free conditions at planting. Multiple different soybean systems were tested, each with similar weed management programs, differing only by POST herbicides. The soybean systems included were: conventional, glyphosate-resistant (1st and 2nd generation), glufosinate-resistant, and dicamba + glyphosate-resistant. For the remainder of this paper, the previous systems will be referred to as their commercial trademarked names: conventional, Roundup Ready 1, Roundup Ready 2, Liberty Link, and Roundup Ready 2 Xtend, respectively. The weed management programs included a nontreated, hand-weed, PRE-only, POST-1-only, and PRE fb POST for each soybean system. Herbicide programs reflect a common or possible strategy used in each soybean system for this region. Plots were 9 m long by 3 m wide consisting of 4 rows with 76-cm spacing. A split-plot design consisting of four replications was used with soybean system as the main plot and weed control program as the subplots. Weed control programs were randomized within each main plot. Yields were adjusted to a 13% moisture content. Best management practices (BMP) and label restrictions were followed for all herbicide applications. Soybean varieties were selected based on similar disease packages, and similar relative maturity (3.7-4.3). The soybean systems were also subjected to two different regimes: one in no-till and glyphosate + PPO-inhibitor-resistant common waterhemp, and the other in conventional-till and no documented herbicide resistance.

The dataset in this study consists of a total of 767 observations. The data was subjected to a multiple regression analysis in an attempt to explain variation in soybean yield as an effect of the independent variables: year, location, herbicide program, and soybean system. Each of the independent variables are qualitative statistics so it was necessary to transformation them to dummy variables. In a regression analysis dummy variables must be compared against a baseline variable. This baseline variable is set =0 and the remaining dummy variables coefficients are set =1 and interpreted as a comparison to the baseline variable. The baseline dummy variables excluded from the model are: 2016 for year, Dowell for location, non-treated for herbicide program, and conventional for soybean system. The expanded model used for this study can be expressed as:

(1) Grain yield = $\beta_0 + \beta_1$(Year-2017) + β_2 (Location-Belleville) + β_3 (Pre-only) + β_4(POST-only) + β_5(Pre-fb-Post) + β_6(Weed-free) + β_7(Xtend) + β_8(Roundup-ready^2) + β_9(Roundup-ready^1) + β_{10}(Liberty-Link) +ε_i

The coefficients for each variable in the regression model will be subjected to a t-test in order to measure their significance in regards to the dependent variable, yield. The results of these tests will allow us to measure the relationship between yield and the independent variables. The regression coefficient results will then be utilized to preform and economic return on investment (EROI). The economic analysis will be conducted as gross return minus treatment cost. Gross return will be determined by a 10 year (2008-2018) average soybean price multiplied by the yield benefit of treatment. The 10 year average soybean price is $11.05 (FarmDoc.com). The cost of treatment will be based on the 2019 non-discounted price of herbicides and recommended adjuvants, a \$5.75 per acre application fee, a \$21.74 per acre seed technology fee for glyphosate and dicamba-resistant soybean systems, and a \$19.49 per acre seed technology fee for glufosinate-resistant soybean systems. EROI will be determined by the following equation:

EROI = [(treated yield) – (nontreated yield)] X (\$/bu/grain) – treatment cost.

It is likely that soybean systems will not be statistically significant for determining soybean yield due to the ability to control for all other variables being provided by the regression model. Herbicide programs should result in statistically significant positive increases in yield compared to nontreated plots. These increases in yield will grow incrementally from PRE-only to PRE-fb-POST having the greatest positive impact on yield. It is expected that year and location will have negative coefficients due to weather patterns that occurred. Both independent variables of year and weather are important to control. However, they are not the primary focus of this paper and will not be discussed in depth. For more information on the impact of weather in during the 2016 and 2017 growing seasons, and its direct impact on each location please reference the study by Geiger (2018).

CHAPTER 4

RESULTS

The results from the multiple regression analysis can be viewed in table 2 and are as follows: The coefficient of the constant term is 22.242 with a t-statistic of 16.018. Year had a coefficient of -10.508 and t-statistic of -13.100. We can conclude that 2017 yielded 10.508 bu/acre less than 2016, all else equal. Location had a coefficient of -9.626 and t-statistic of -12.000. We can conclude that Belleville yielded 9.626 bu/acre less than Dowell, all else equal. PRE-only had a coefficient of 14.317 and a t-statistic of 10.311. We can conclude that PRE-Only herbicide programs yielded 14.317 bu/acre more than nontreated, all else equal. POST-only had a coefficient of 28.531 and t-statistic of 20.548. We can conclude that POST-only herbicide programs yielded 28.531 bu/acre more than nontreated, all else equal. PRE-fb-POST had a coefficient of 37.739 and t-statistic of 27.180. We can conclude that PRE-fb-POST herbicide program yielded 37.739 bu/acre more than nontreated, all else equal. Weed-free had a coefficient of 36.830 and t-statistic of 22.910. We can conclude that weed-free (hand weeded) plots yielded 36.830 more bu/acre than nontreated plots, all else equal. Xtend soybean systems had a coefficient of -2.230 and t-statistic of -1.854. We can conclude that Xtend soybean systems yielded 2.230 bu/acre less than conventional soybeans, all else equal. Roundup Ready 2 soybean systems had a coefficient of -3.865 and t-statistic of -3.206. We can conclude that Roundup Ready 2 soybean systems yielded 3.865 bu/acre less than conventional soybeans, all else equal. Roundup Ready 1 soybean systems had a coefficient of 2.324 and t-statistic of 1.932. We can conclude that Roundup Ready 1 soybean systems yielded 2.324 bu/acre more than conventional soybeans, all else equal. Liberty Link soybean systems had a coefficient of -1.464 and t-statistic of -1.218. We can conclude that Liberty Link soybean systems yielded 1.464 bushels/acre less than conventional soybeans, all else equal.

Utilizing a confidence interval of 5% and critical value of 1.970 for all t-tests, we can conclude that the independent variables: year, location, PRE-only, POST-only, PRE-fb-POST, weed-free, and Roundup Ready 2, are all statistically significant in explaining yield. The results of the year, location and herbicide programs are in line with the expected outcome, as each herbicide program progression should offer better weed control. Xtend, Roundup Ready 1, and Liberty Link soybean systems are not statistically significant; this is in line with expectations. It was predicted that soybean systems would not perform differently. This would suggest that the yield is determined primarily by herbicide program, not soybean system. However, the Roundup Ready 2 system is statistically significant, but also has a negative sign, which in not in line with industry assumptions. Furthermore, the negative signs for Xtend and Liberty Link were also unexpected and are difficult to explain. It is suspected to be due to genetic differences in seed and varieties and environmental conditions presented during the growing season. The Weed-Free treatment had a smaller positive impact on yield than PRE-fb-POST. This is logical considering that for a weed to be removed by hand it must first be large enough to see and therefore, it has already taken nutrients away from the plant, up to the point of removal. Explanations for the negative signs for both year and location are described in greater detail in Geiger (2018) original study and are not the main focus of this paper, so therefore excluded from the results.

All herbicide programs resulted in an increase in yield compared to non-treated, as expected. The costs of different herbicide programs were largely similar across each soybean system and therefore combined for simplicity. Gross return increased from $158.17 with PRE-only herbicide programs to $416.95 with PRE-fb-POST programs. POST-only gross return fell in between the latter two programs at $315.20. Treatment costs nearly doubled from $36.35 in PRE-only programs to $71.56 in PRE-fb-POST programs. EROI for PRE-only, POST-only, and PRE-fb-POST are as follows: $121.83, $273.15, and $345.39 respectively. With this information we can conclude that POST-only programs result in a $151.33 greater EROI than PRE-only programs. PRE-fb-POST results in $72.24 greater EROI than POST-only as well (Table 2). Weed-Free EROI is excluded from the EROI as it would not be economically or physically feasible to hand weed entire fields in a modern row crop operation. This EROI data suggests that regardless of the presence of herbicide resistant weeds, an effective BMP herbicide program is more economically beneficial to a farming operation, despite having higher costs, than that of SP herbicide programs such as POST-only.

CHAPTER 5

DISCUSSION

The results discussed above are largely consistent to results from the original study by Geiger (2018). This reinforces the idea that a multiple regression model can be a useful statistical method to assess and analyze the impact of various weed management programs in soybeans, while controlling for common variables. From this study we can conclude that following BMPs, and specifically a PRE-fb-POST herbicide program is not only a more sustainable practice for long term weed management, but also the most economically beneficial for growers.

Table 1: Regression

Dependent Varibale: Yield
Method: Least Squares
Included observations:767

Variable	Coefficient	Std. Error	T-statistic	P-value
C	22.24258	1.388569	16.01835	0.0000
Year	-10.50860	0.802178	-13.10007	0.0000
Location	-9.626819	0.802178	-12.00084	0.0000
PRE-only	14.31771	1.388492	10.31169	0.0000
POST-only	28.53125	1.388492	20.54837	0.0000
PRE-fb-POST	37.73958	1.388492	27.18026	0.0000
WeedFree	36.83019	1.607546	22.91082	0.0000
Xtend	-2.230469	1.202470	-1.854907	0.0640
RR2	-3.865636	1.205659	-3.206243	0.0014
RR1	2.324219	1.202470	1.932871	0.0536
LL	-1.464844	1.202470	-1.218196	0.2235
R-Squared	0.646646			
Adjusted R-Squared	0.641972			
F-statistic	138.3498			

Table 2: EROI

Economic Return on Investment

	Gross Return	Treatment Cost	Net Benefit
PRE	$ 158.17	$ 36.35	$ 121.83
POST	$ 315.20	$ 42.05	$ 273.15
PRE-fb-POST	$ 416.95	$ 71.56	$ 345.39

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